Program Options to Explore Ocean Worlds

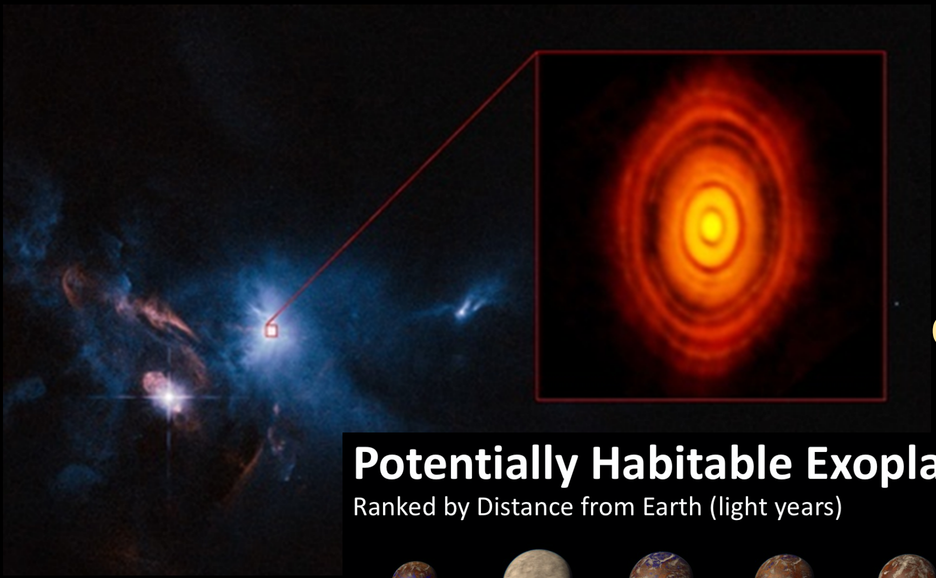
B. Sherwood J. Lunine C. Sotin T. Cwik F. Naderi K. Hand

42nd COSPAR Assembly, Pasadena, 20 July 2018

Jet Propulsion Laboratory
California Institute of Technology

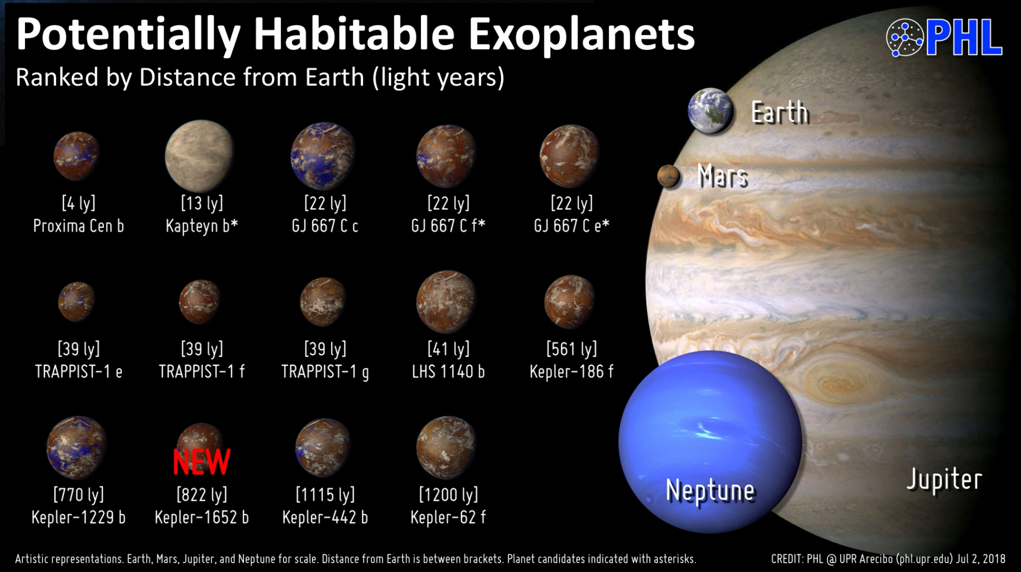
© 2018 California Institute of Technology. Government sponsorship acknowledged.

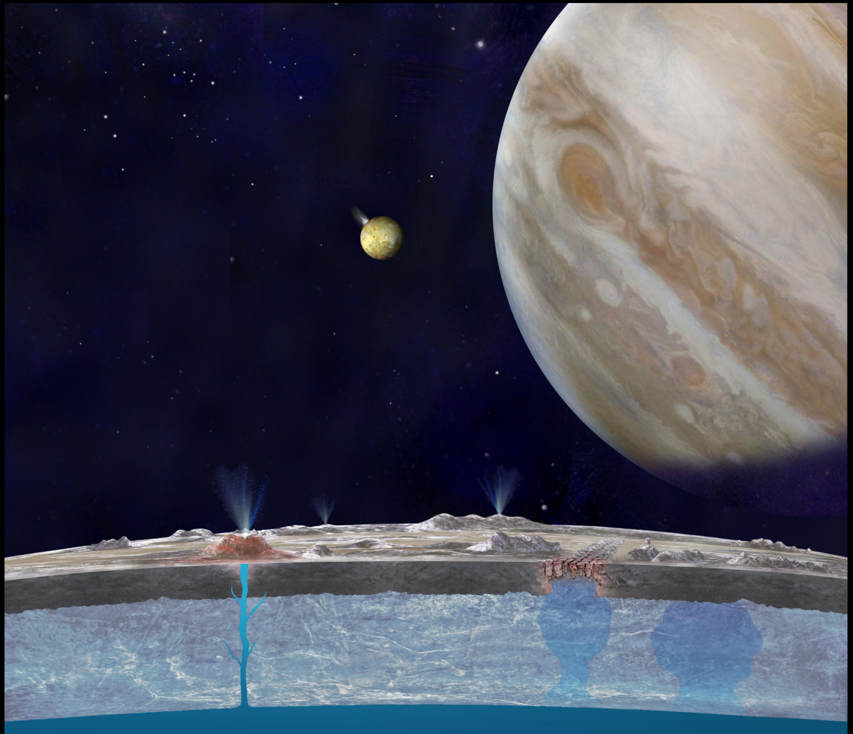
Is there life elsewhere in the universe?



Indirect search:

observation of extra-solar planets



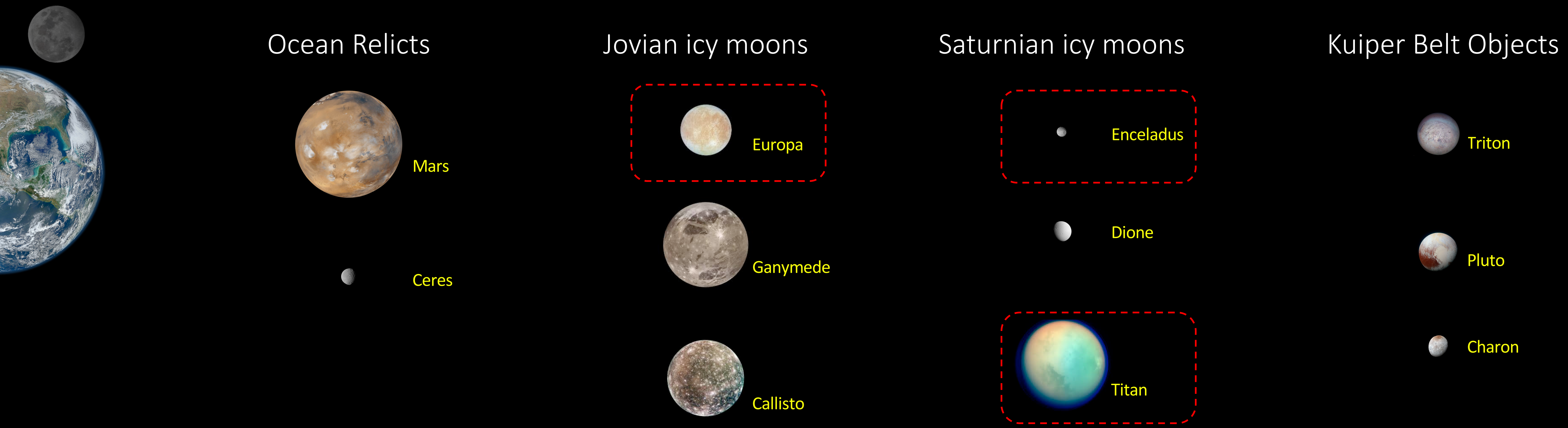


Tangible search:

life in the ocean worlds of our solar system

Ocean worlds contain vast quantities of water

More than a dozen ocean worlds within reach



Six steps to “find and understand life elsewhere”

1. Find liquid water
2. Quantify its habitability
3. Detect biosignatures in it
4. Confirm that life is present
5. Understand how that life operates
6. Learn the limits of life

Program scenarios for a NASA OWEP

Case 0a – Status quo

Case 0b – Select Dragonfly in 2019

Case 1 or 2 would cost 1/40th of NASA budget

Case 1 – Select two New Frontiers missions every 5 years, one for OW

Case 2 – Compete $1B-class directed-purpose OW mission every 5 years

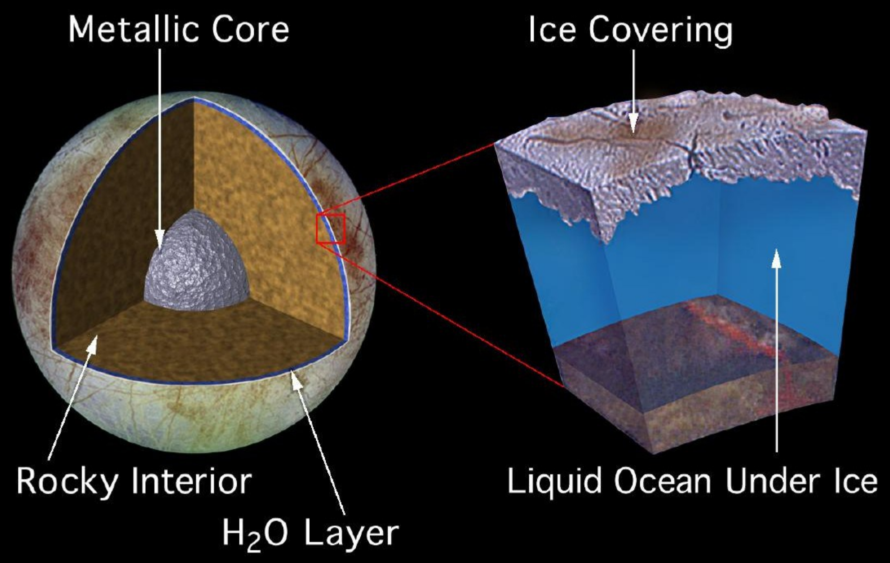
Case 3a – Add strategically managed OW Technology Program

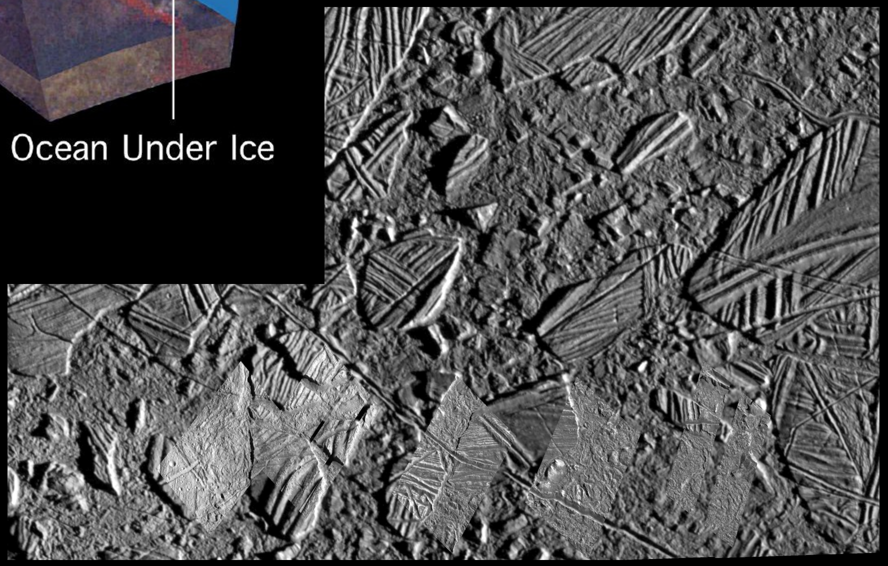
Case 3b – Establish a line-item OW Exploration Program

The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

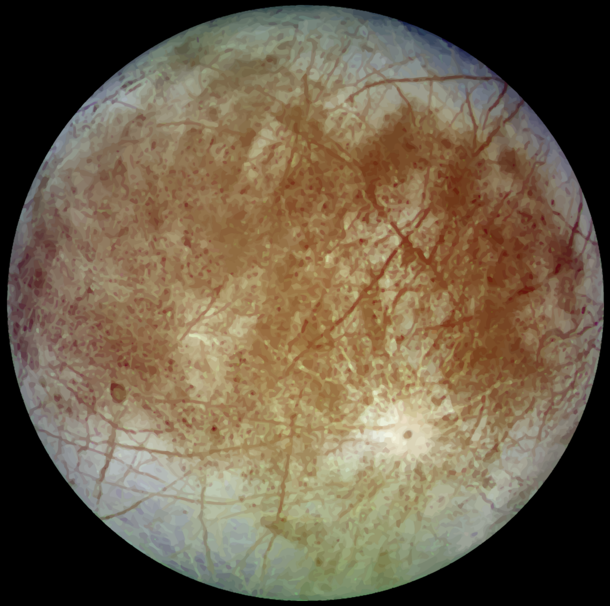
Europa: best place for life?

- Almost as large as Earth's Moon
- Ocean in contact with silicate rock
- Plausible mechanism to sustain redox disequilibrium



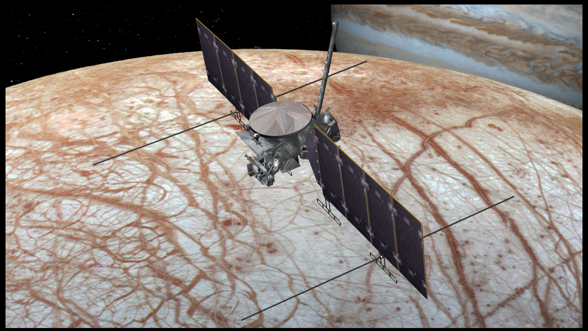


A Europa program in three steps



Comprehensive investigation of the icy moon's habitability

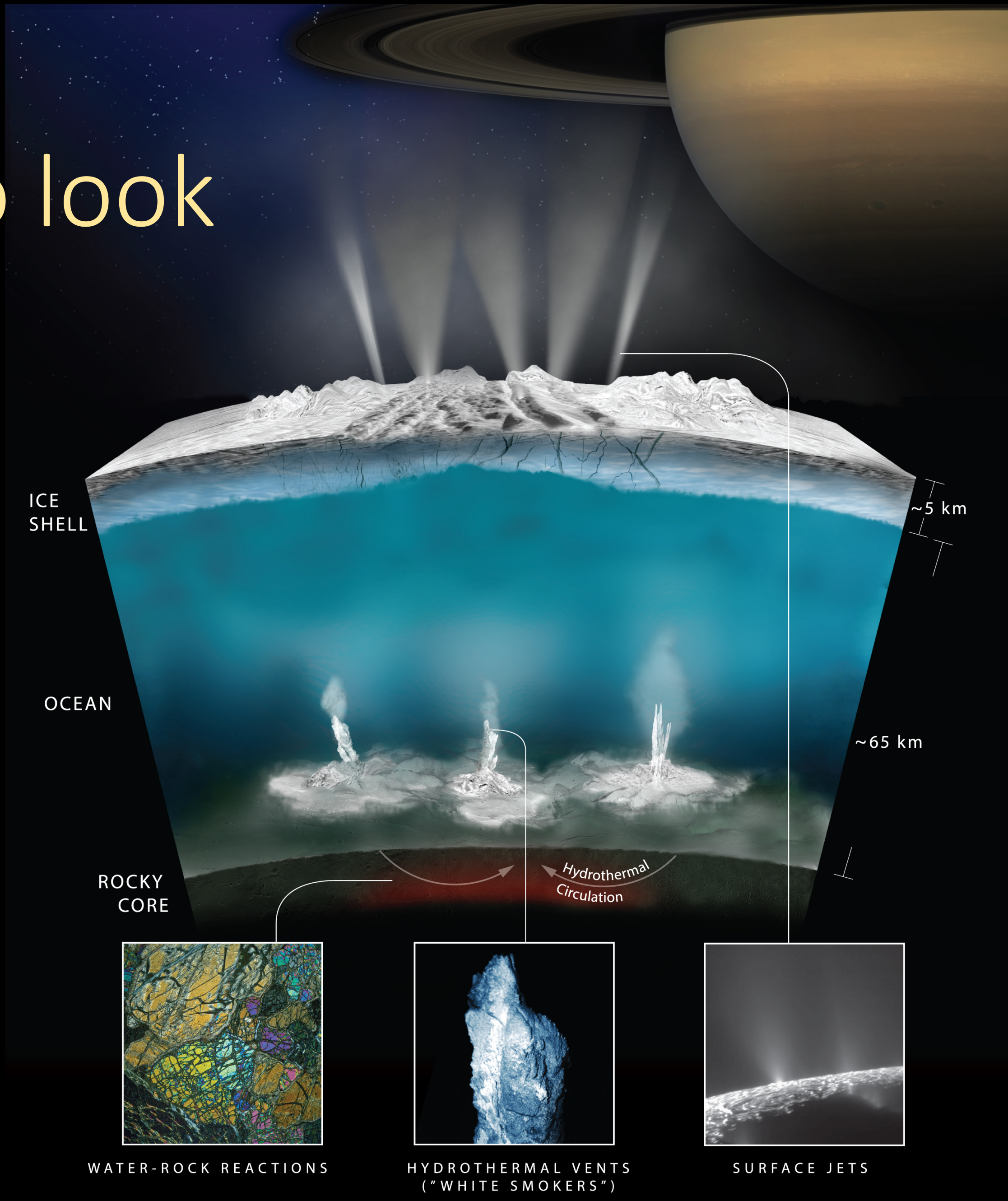
- Near-global hyper mapping
- Lander-scale surface imagery



- Land at ocean-surface exchange zone
- Mobility around touchdown point
- Subsurface access to pursue fresher material
- Trans-shell probe into ocean, sample return
- Under-ice exploration of ocean ceiling
- Open ocean exploration, including seafloor

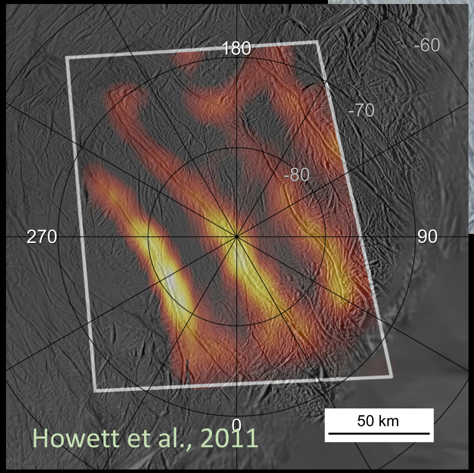
Enceladus: easiest place to look

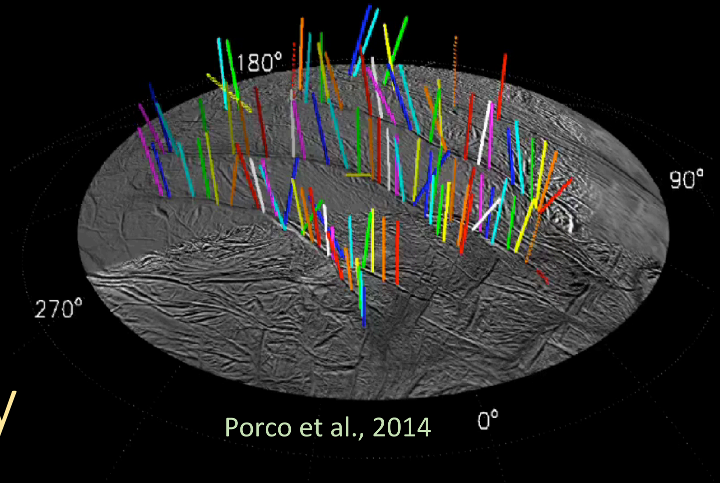
- The most habitable place we know so far
- Salt-water ocean with hydrothermal activity
- Predictably expressed into space by a big plume, ripe for sampling

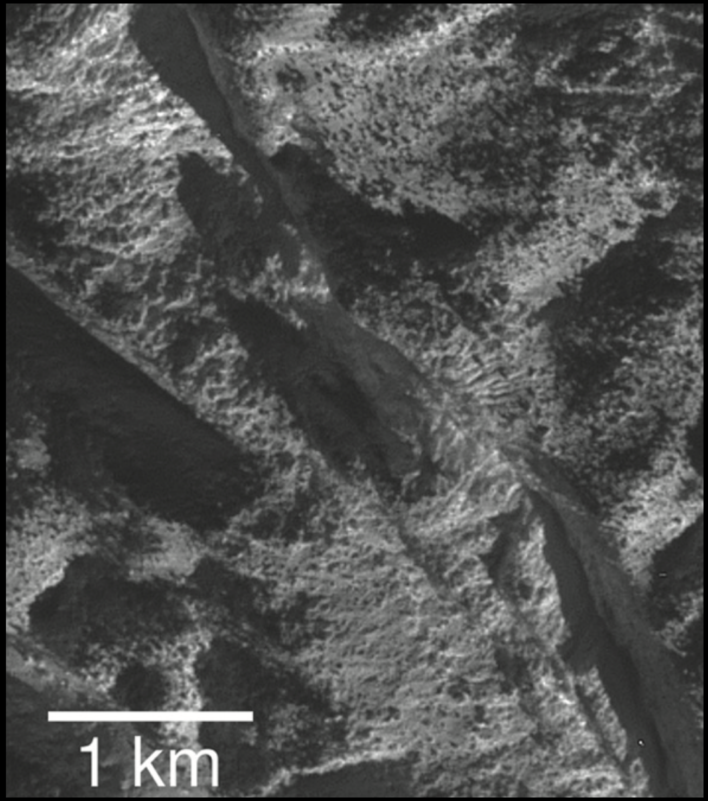


Awaiting focused missions

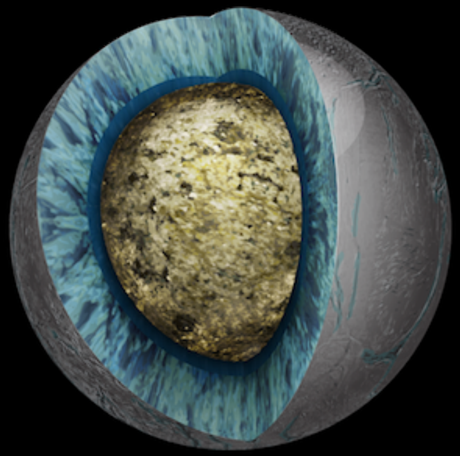
- Ice crust split by warm fissures
- > 100 geysers send large plume far into space, easy to transect
- Ice grains include silica dust and frozen ocean spray
- Salt water, hydrothermal circulation, organic chemistry







An Enceladus program in three steps



Direct access to material known to originate in a habitable place

- Plume transects
- Best compositional analyzers

Wet-chemistry and microscopy of grain material

Collection, preservation, and return of samples

Surface collection of large amounts of material

'Downhole' access to the foaming interface

Under-ice exploration of ocean ceiling

Open ocean exploration, including seafloor hydrothermal systems known to exist

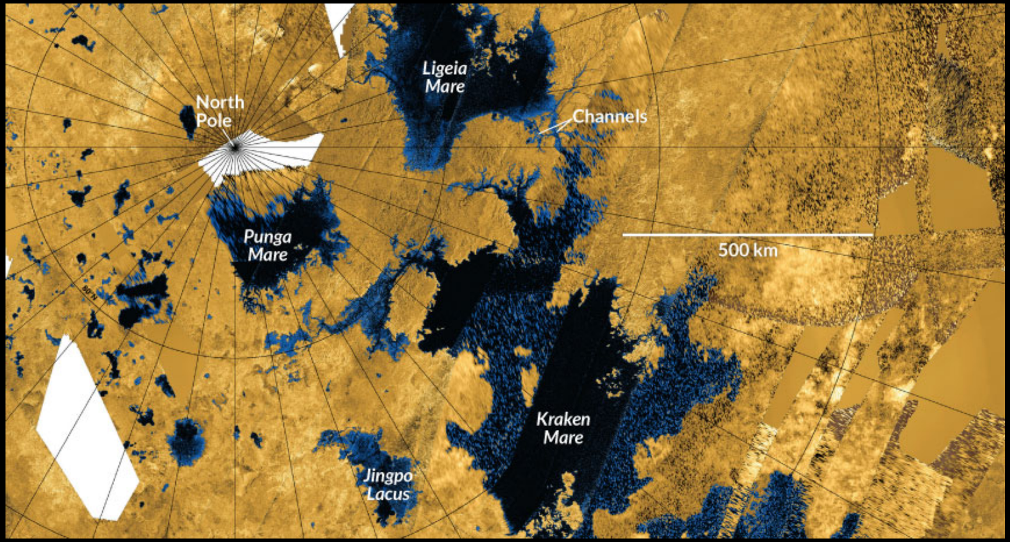
Titan: best place to look for weird life?

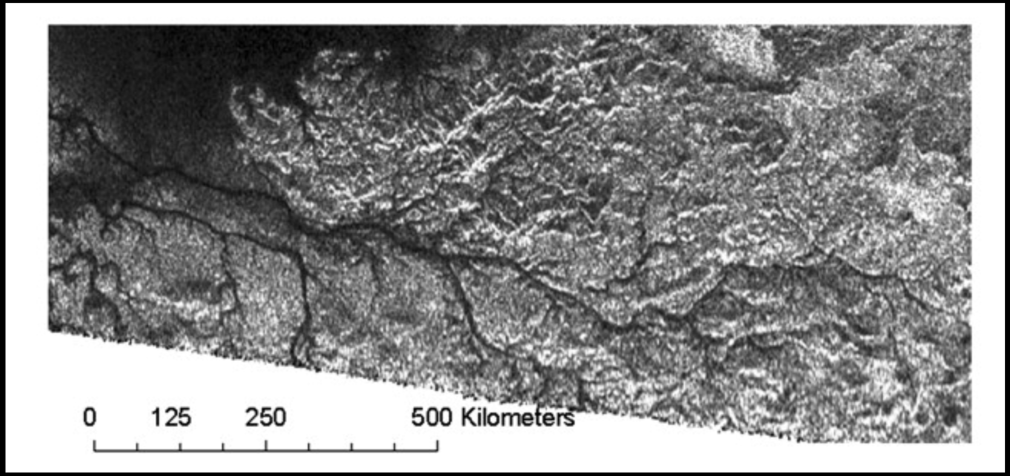
- Large organic molecules capture energy from sunlight in upper atmosphere

- Methanogenic cycle weathers organic sediment on surface

- Vast, global interior salt-water ocean

- Where and how do the organics interact with the water?

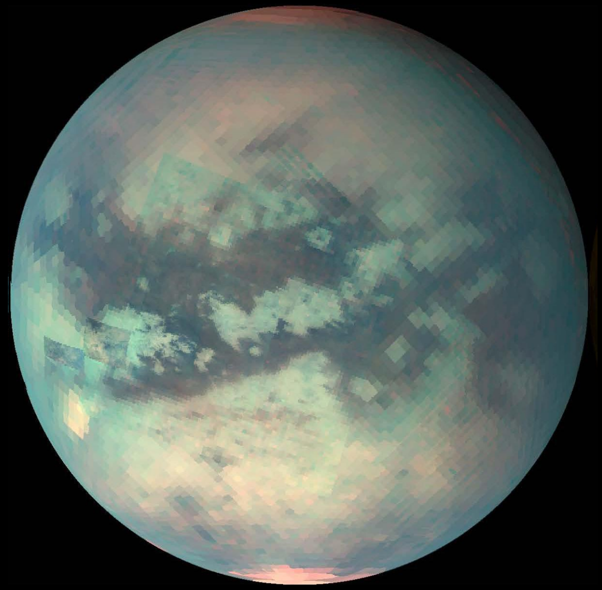


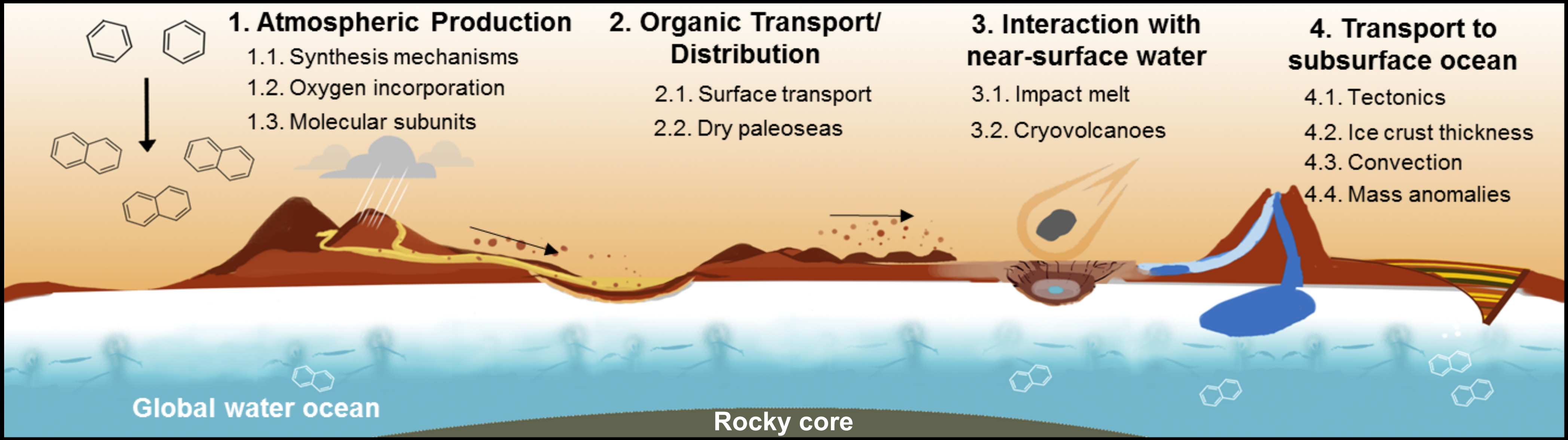


Jaumann et al., 2008

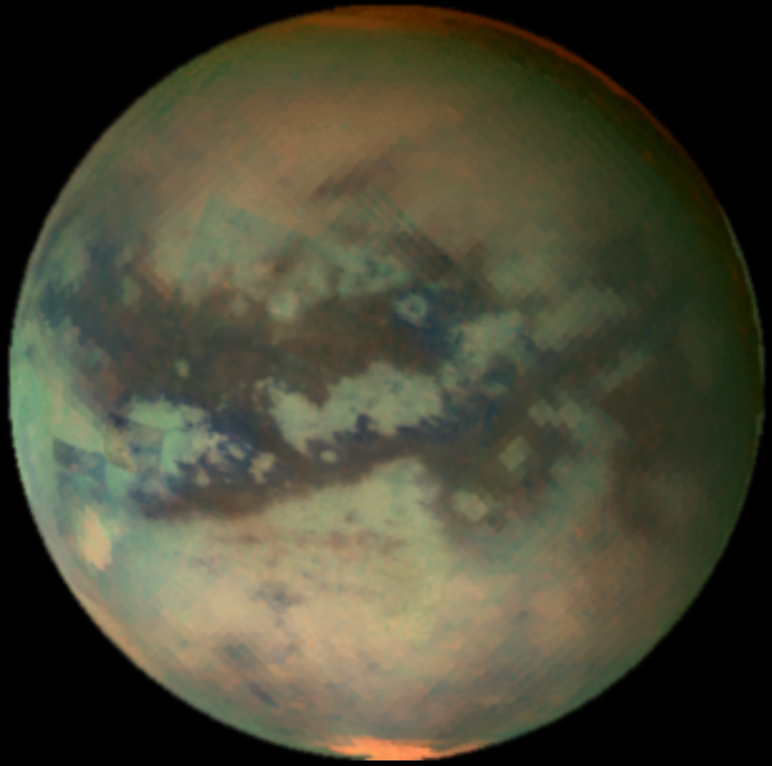
A world of two oceans

- Earth used to be a "pale orange dot" too
- How far can organic chemistry evolve without life?





A Titan program in three steps



Comprehensive reconnaissance of a complex world

- Atmospheric organics factory
- Global surface mapping
- Gravity, tidal mapping

Aerial exploration

Buoyant sea exploration

Mobile surface exploration

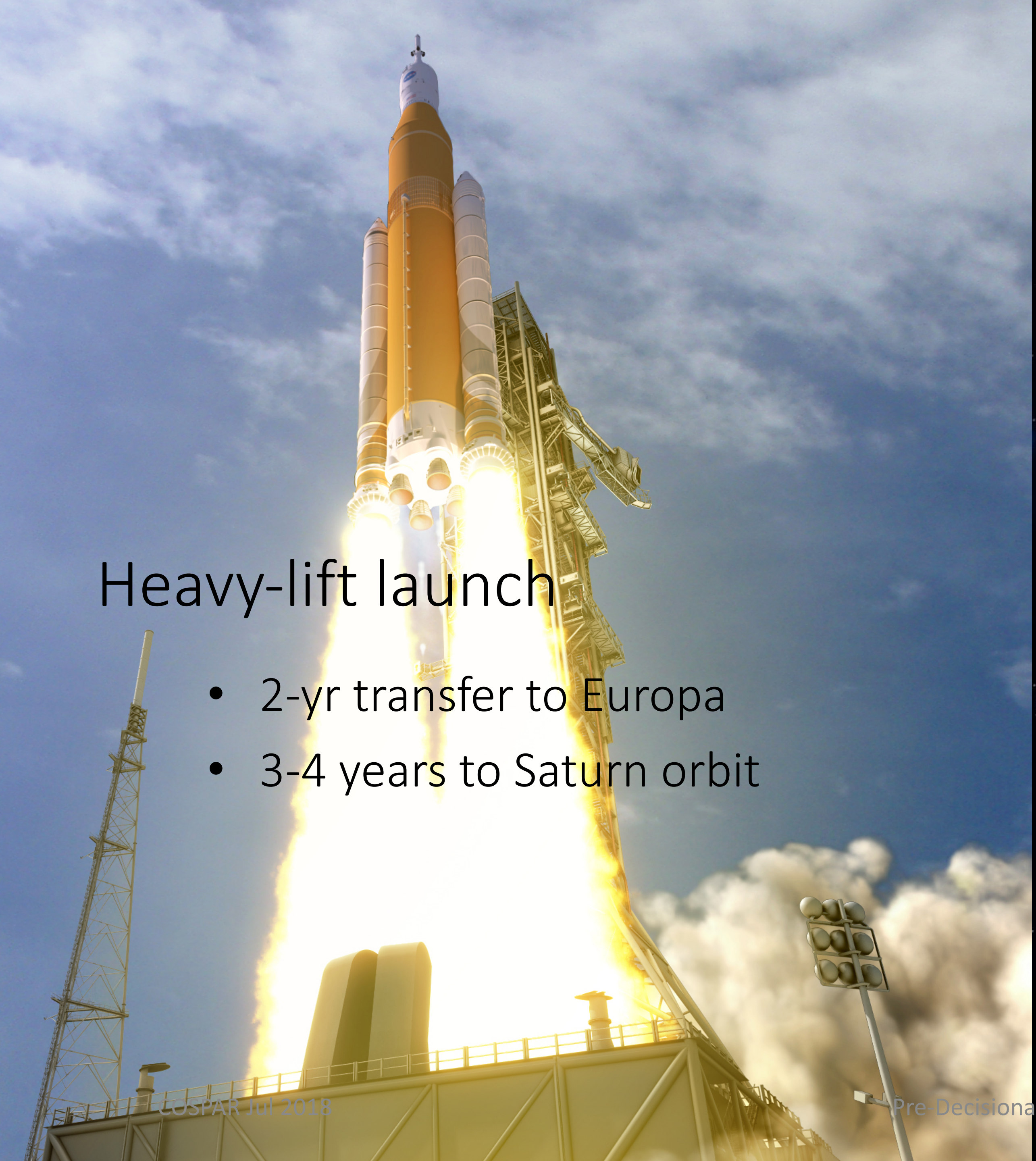
In situ analysis of weathered organics

Sample return

Through-crust ocean access

From MEP to OWEP

- Mars is technically moderate compared to the icy ocean worlds
- Mars missions can respond to new knowledge on half-decade cadence
- Projects managed within a program allow rapid progress
- Shared operational infrastructure ‘lowers the bar’ for each mission
- Core capabilities should be developed outside individual flight projects
- Medium-class directed-purpose missions form ‘connective tissue’



Heavy-lift launch

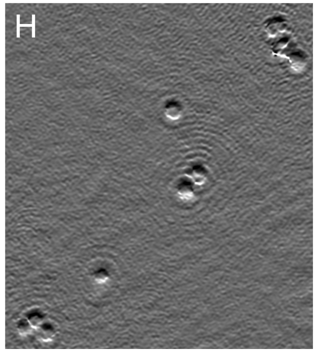
- 2-yr transfer to Europa
- 3-4 years to Saturn orbit

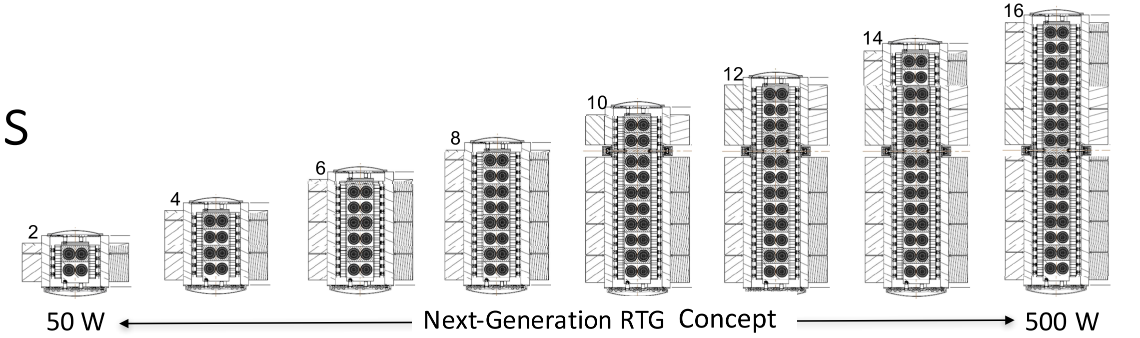
Solar Electric Propulsion

- 25 kW-class commercial systems available today
- 5-6 years to Saturn with standard LV
- Mission-scalable

Key technologies are common to all targets

- Planetary protection of and from ocean-world material
- "Life-detection" measurement techniques and instruments
- Sample acquisition, handling, preservation
- Cryogenic mechanisms and electronics
- Modular radioisotope power systems
- Autonomous, exploratory science investigations





Jet Propulsion Laboratory
California Institute of Technology